Section 3.1

Water Quality

There are several sources for direct water quality measurements for the upper Neversink River. The following sources provide the bulk of available information:

- NYCDEP has an extensive and comprehensive set of data from the upper Neversink watershed as part of its long-term water quality monitoring of the NYC drinking water supply. Currently NYCDEP maintains a monitoring site on the Neversink River at Claryville (NYCDEP, 2009). Data from this site are discussed below.
- The United States Geological Survey (USGS) currently operates seven gaging stations for streamflow within the upper Neversink River Watershed: East Branch Neversink River Northeast of Denning (id# 0143400680) (Period of record: 10/01/1990-present), East Branch Neversink River near Claryville (id# 01434017) (Period of record: 07/01/1991-present), West Branch Neversink River at Winnisook Lake near Frost Valley (id# 01434021) (Period of record: 01/01/1991-present), Biscuit Brook Above Pigeon Brook at Frost Valley (id# 01434025) (Period of record: 06/08/1983-present), Shelter Creek Below Dry Creek near Frost Valley (id# 01434092) (Period of record: 10/01/1992-present), West Branch Neversink River at Claryville (id# 01434498) (Period of record: 07/01/1991-present), Neversink River near Claryville (id# 01435000) (Period of record: 11/01/1937-present).
- The USGS, under contract to NYC DEP, collected water quality data at four locations from 1991-2010 in the Neversink Watershed: East Branch Neversink River northeast of Denning, West Branch Neversink River at Winnisook Lake near Frost Valley, Biscuit Brook above Pigeon Brook at Frost Valley, and Neversink River near Claryville (The data are available at: http://ny.cf.er.usgs.gov/nyc/unoono.cfm.).
- The USGS established the Hydrologic Benchmark Network (HBN) in 1963 to provide long-term measurements of streamflow and water quality in areas that are minimally affected by human activities (http://ny.cf.er.usgs.gov/hbn/index.cfm). In 2003, the USGS re-established a 15-station water-quality and 36-station discharge monitoring network with a new design that allows tracking of trends in water quality at a range of river flow conditions. The Neversink River at Claryville was included as one of the water-quality stations. In fact, the USGS has collected water quality from this site since 1954.
- The USGS has also conducted a number of scientific studies in the upper Neversink watershed. These include studies on the impacts of acid rain, mercury deposition, forestry practices on water quality and biota in the watershed. Reports can be found on the USGS New York Water Science Center website at: http://ny.water.usgs.gov/.
- In 2000, Stroud Water Research Center located in Pennsylvania was awarded a Safe Drinking Water Act (SDWA) grant funded by the New York State Department of Environmental Conservation and the USEPA to conduct a six-year study to monitor and evaluate water quality and sources of pollution

in the streams, rivers, and reservoirs that provide New York City's (NYC) drinking water. There were three sites in the Neversink River watershed included in the study that were variably sampled from 2000-2003. Copies of the final report can be found at: (http://www.stroudcenter.org/research/newyorkproject.htm).

- NYSDEC, Routine Statewide Monitoring Program provides for the routine monitoring of the waters of the State to allow for the determination of the overall quality of waters, trends in water quality, and identification of water quality problems and issues. This monitoring effort is coordinated through the Rotating Integrated Basin Studies (RIBS) Program which typically operates on a 5-year cycle (The Neversink River Watershed will be monitored from 2009-2011 as part of the Delaware River assessment.). The water quality data and information collected by this program are used to support assessment and management functions within NYSDEC Division of Water (DOW), including the Waterbody Inventory/Priority Waterbodies List (WI/PWL), New York State's Clean Water Act Section 305(b) Water Quality Report, and Section 303(d) List of Impaired Waters of the state. Contacts for the program staff, which can provide relevant reports, are available at their website: http://www.dec.ny.gov/chemical/30951.html.
- NYSDEC also maintains a Stream Biomonitoring Program that uses resident benthic macroinvertebrate communities as indicators of water quality in rivers and streams. This program was begun in 1972, and has been instrumental in identifying temporal trends in water quality statewide. Sites in the upper Neversink River watershed have been included in this program. Additional information can be found at http://www.dec.ny.gov/chemical/23847.html.

NYCDEP has a long-term water quality sampling program of streams in the NYC water supply watersheds. Water quality samples are collected at a fixed frequency from a network of sampling sites throughout the watershed. Grab samples are generally collected once a month. Storm event sampling is also performed at selected sites. While the analyses performed on samples from a specific site vary somewhat based on the objectives for the site, in general, samples are tested for temperature, pH, alkalinity, specific conductivity, dissolved oxygen, turbidity, nutrients, dissolved organic carbon, total organic carbon, chloride, suspended solids (selected sites), major cations (Ca, Mg, Na, K) (analyzed monthly), and total and fecal coliform (most sites). The current monitoring system was re-designed in 2008 and was based on multiple objectives (NYCDEP, 2009), and included a sampling site on the Neversink River at Claryville. Results are presented in annual water quality monitoring reports (e.g. NYCDEP, 2010).

Constituents of Neversink Water

The following section provides a summary of the major parameters that are tracked by NYCDEP in the Neversink River. Combined, these parameters provide a basic overview of water quality, while potentially allowing for a general understanding of human-induced changes to water quality. The NYCDEP data reported here are annual medians for selected water quality variables. The median is a statistic that expresses the "typical" condition of something. The median is simply the value in the center of a data set, i.e. half of the samples are higher, and half lower. One characteristic of the median is that it is not overly influenced by data from extreme events. The data from this site contains values that were reported as "less than" a detection limit, i.e. censored data. In those cases where censored data were found a Minitab® macro written by Dr. Dennis Helsel of Practical Stats®, which uses a non-parametric statistical procedure known as Kaplan-Meier, was used to calculate the descriptive statistics presented below. Also, the results are based on routine grab samples, and do not specifically target extreme events.

Turbidity and Total Suspended Solids

Turbidity is an index of water clarity. The regulatory water quality standard for turbidity in New York State surface water is a narrative standard: "no increase that will cause a substantial visible contrast to natural conditions" (NYCRR, Title 6, Section 703.2). There is also a narrative water quality standard for suspended, colloidal, and settleable solids: "None from sewage, industrial wastes or other wastes that will cause deposition or impair the waters for their best usages." Although there are no numerical standards for turbidity or suspended sediment, these constituents are of concern in streams because the presence of fine-grain sediments such as clay particles suspended in the water column can affect stream biota. These fine sediments can settle on substrates used by colonizing algae and invertebrates and can fill the small spaces between gravel where fish lay their eggs. Transmission of light through the water can be reduced, which can affect stream productivity through decreased photosynthesis. Turbid waters also become warmer as suspended particles absorb heat from sunlight, which can also cause oxygen levels to fall. From the perspective of drinking water, the Safe Drinking Water Act and associated regulations are concerned with turbidity levels entering the distribution systems for public water systems; accordingly, from a Safe Drinking Water Act perspective, DEP's primary concern is the level of turbidity in water leaving the Kensico reservoir (Westchester County). For purposes of drinking water, turbidity is of concern because the associated particles have the potential to mask pathogens and interfere with disinfection.

Turbidity is an optical measurement of the light-scattering at 90° caused by particles suspended in water. Turbidity is measured in arbitrary "nephelometric turbidity units" (NTUs) by a "nephelometer". The higher the NTU value, the lower the water clarity. Turbidity can be influenced not only by the amount of particles in suspension, but also by the shape, size, and color of the particles. There is no single, fixed relationship between turbidity and total suspended solids. Total suspended solids are a measure of suspended solids concentration, expressed as a mass per volume (mg/L) obtained by physically separating the liquid and solid phases by filtration.

The median turbidity value for the Neversink River near Claryville based on data from 1987-2009 is 0.7 NTU. While the Neversink River usually has fairly low turbidity values, storms can cause these numbers to increase by three orders of magnitude. For example, samples collected during storm events have had turbidities as high as 750 NTU. Likewise the median value for total suspended solids is 0.6 mg/l, but during storm events has reached almost 2,900 mg/l.

Table 1. Annual descriptive statistics for turbidity (NTU) at Neversink River near Claryville, 1987-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	26	0.3	0.4	0.5	0.6	3.1
1988	26	0.2	0.5	0.7	1.0	3.0
1989	27	0.3	0.6	1.0	1.4	3.4
1990	26	0.3	0.5	0.6	1.2	4.0
1991	27	0.2	0.4	0.5	0.9	2.7
1992	26	0.1	0.3	0.5	0.7	60.0
1993	26	0.1	0.2	0.2	0.4	1.4
1994	26	0.1	0.2	0.3	0.5	1.7
1995	25	0.1	0.2	0.3	0.4	1.2
1996	26	0.2	0.3	0.6	1.0	2.4
1997	26	0.2	0.3	0.4	0.4	1.0
1998	25	0.2	0.3	0.4	0.6	4.4
1999	26	0.2	0.3	0.4	0.5	3.3
2000	25	0.1	0.3	0.4	0.5	5.0
2001	26	0.2	0.3	0.4	0.7	20.0
2002	24	0.2	0.3	0.4	0.6	1.2
2003[1]	24	<0.3	*	*	*	8.4

2004	24	0.2	0.3	0.4	0.5	3.7
2005	24	0.2	0.3	0.5	0.8	1.8
2006	24	0.2	0.4	0.4	0.8	4.6
2007	24	0.2	0.4	0.5	0.6	0.9
2008	24	0.2	0.3	0.4	0.7	6.9
2009	11	0.1	0.2	0.3	0.4	0.8
Overall	**568**	**<0.3**	**0.4**	**0.7**	**1.2**	**60.0**

[1] The descriptive statistics for this period were estimated using a Kaplan-Meier method. * indicate that not enough non-censored data were available to make an estimate.

Table 2. Annual descriptive statistics for total suspended solids (mg/l) at Neversink River near Claryville, 1989, 1994-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1989	9	0.0	0.3	0.4	1.2	2.5
1994	10	0.3	0.6	0.7	0.9	1.0
1995	8	0.3	0.5	0.6	1.0	1.2
1996	12	0.2	0.4	0.4	0.7	3.8
1997	11	0.2	0.4	0.4	0.8	3.2
1998	10	0.2	0.4	0.6	2.4	7.8
1999	11	0.1	0.2	0.3	0.4	0.5
2000[1]	11	<0.1	*	0.3	0.7	0.8
2001[1]	7	<0.4	0.2	0.2	0.9	11.6

2002[1]	24	<0.4	*	0.4	0.6	4.6
2003[1]	24	<0.2	0.2	0.4	0.8	21.5
2004[1]	24	<0.3	0.2	0.4	0.6	6.3
2005[1]	24	<0.3	0.2	0.5	1.3	2.8
2006[1]	24	<0.3	*	0.3	0.6	8.2
2007[1]	24	<0.3	*	*	0.5	1.1
2008[1]	23	<0.3	*	*	*	8.0
2009[1]	12	<0.3	*	0.4	0.8	1.0
Overall	**268**	**<0.1**	**0.4**	**0.6**	**1.3**	**22**

[1] The descriptive statistics for this period were estimated using a Kaplan-Meier method. * indicate that not enough non-censored data were available to make an estimate.

Pathogens

NYCDEP monitors for pathogens, specifically *Giardia* and *Cryptosporidium*, in the Catskill mountain streams. While there are no regulatory thresholds for these protozoa in surface waters, NYCDEP maintains a monitoring program for them due to their potential negative effects on public health. These protozoa are of concern to public health for two reasons: 1) if consumed, certain strains of these protozoa can cause disease in humans, and 2) the presence of these protozoa indicates that the water has been contaminated with fecal matter (animal or human) and; therefore, may be carrying other pathogens that have the potential to cause disease in humans.

Protozoan sampling was conducted at sites NEBG and NWBR, on the east and west branches of the Neversink River, respectively, from 2003-2006 and NCG on the Neversink River from 2002-2008. The results, based on 67 and 68 samples for *Cryptosporidium* and *Giardia*, respectively, indicate very low mean and median *Cryptosporidium* and *Giardia* (oo)cyst concentrations based on 50-L samples (Table 3).

Table 3. Basic statistics for protozoan sampling sites NEBG, NWBR, and NCG on Neversink River.

	NEBG *Crypto* $\cdot 50L^{-1}$	NEBG *Giardia* $\cdot 50L^{-1}$	NWBR *Crypto* $\cdot 50L^{-1}$	NWBR *Giardia* $\cdot 50L^{-1}$	NCG *Crypto* $\cdot 50L^{-1}$	NCG *Giardia* $\cdot 50L^{-1}$
# of samples	11	11	11	11	73	72
Mean	1.73	0.82	0.36	6.91	0.38	37.34
Median	0	0	0	2	0	20
Max	13	5	1	30	3	211

The samples were analyzed using USEPA Method 1623, the nationally accepted method for enumerating *Cryptosporidium* and *Giardia*. Similar to data at other sites in the NYC watershed, *Giardia* concentrations were higher than *Cryptosporidium*. The maximum result obtained for *Giardia* was 211 cysts, and for *Cryptosporidium* was 13 oocysts. These values are comparable to the maximum results for many other sites within the West-of-Hudson watershed (NYCDEP, 2009).

Temperature

Water temperature is one of the most important variables in aquatic ecology. Temperature affects movement of molecules, fluid dynamics, and metabolic rates of organisms as well as a host of other processes. In addition to having its own potential "toxic" effect (i.e. when temperature is too high), temperature affects the solubility and, in turn, the toxicity of many other parameters. Generally the solubility of solids increases with increasing temperature, while gases tend to be more soluble in cold water (i.e. available O_2 to fish).

In densely wooded areas where the majority of the streambed is shaded, heat transferred from the air and groundwater inputs drive in-stream temperature dynamics. However, in areas that aren't shaded the water temperatures can rise much more quickly due to the direct exposure to the sun's radiation. Rock and blacktop also hold heat and can transfer the heat to the water (like hot coals in a grill). Annual fluctuation of temperature in a stream may drive many biological processes, for example, the emergence of aquatic insects and spawning of fish. Even at a given air temperature, stream temperature may be variable over short distances depending on plant cover, stream flow dynamics, stream depth and groundwater inflow. Water temperatures exceeding 77° Fahrenheit cannot be tolerated by brook trout, and they prefer water temperatures less than 68° Fahrenheit (TU, 2006).

The annual median water temperature of Neversink River from 1987 to 2009 was 7.0°C (44.6°F). The annual median temperature ranged from 4.0°C (39.2°F) (1987) to 9.0°C (48.2°F) (1998).

Phosphorus

Phosphorus is a nutrient essential to plant growth. In aquatic ecosystems phosphorus occurs primarily in the form of organic phosphorus. Organic phosphorus is bound in plant and animal tissue and is unavailable for plant uptake. Phosphate ($PO4^{3-}$) is a form that is available and needed by plants. Plants assimilate phosphate from the surrounding water and convert it to organic phosphorus. In freshwater ecosystems phosphate tends to be the nutrient that is least available for plant growth. Consequently, phosphate is often the limiting factor, and small additions to surface waters can result in large amounts of plant growth and eutrophication.

Phosphate binds to soil particles, which act to slow its transport. The soil-attached phosphate will often settle out in standing water (ponds/lakes/reservoirs), which once disturbed and resuspended, or released due to anoxic conditions, can lead to excessive vegetation growth. The most likely sources of phosphate inputs include animal wastes, human wastes, fertilizer, detergents, disturbed land, road salts (anticaking agent), and storm water runoff. Based upon the average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of total phosphorus (P) and orthophosphate were 0.022 and 0.010 mg/L respectively (Clark et al., 2000). In general, any concentration over 0.05 mg/L of phosphate will likely have an impact on surface waters (Behar, 1996). However, in many streams and lakes concentrations of phosphate as low as 0.01 mg/L can have a significant impact on water resources by causing a proliferation of aquatic vegetation and phytoplankton. In order to control eutrophication, the USEPA recommended limiting phosphate concentrations to 0.05 mg/L in waters that drain to lakes, ponds and reservoirs, and 0.1 mg/L in free flowing rivers and streams (USEPA, 1996). DEP considers the 0.05 mg/L as a guidance value for streams. However, the critical guidance value for the Neversink Reservoir is 0.015 mg/L (NYCDEP, 2010).

The median total phosphorus concentration (1987-2009) for Neversink River was 0.006 mg/l. However, during storm events total phosphorus concentration greater than 1 mg/l have been observed.

Table 4. Annual descriptive statistics for total phosphorus (µg/l) at Neversink at Neversink River near Claryville, 1989, 1994-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987[1]	19	<10	*	*	13	22
1988[1]	26	<2	4	7	11	38
1989	26	3	4	6	7	41
1990[1]	26	<2	4	5	6	14
1991[1]	27	<2	2	3	5	12
1992[1]	26	<2	2	3	4	107
1993	26	2	4	6	6	14
1994	25	2	3	3	5	14
1995[1]	25	<2	3	3	4	7
1996	26	2	2	4	5	22
1997[1]	26	<2	2	3	4	8
1998[1]	25	<2	2	3	7	30
1999[1]	26	<3	*	3	5	19
2000[1]	24	<2	2	3	4	14

2001[1]	25	<2	2	3	4	59
2002[1]	22	<1	2	3	5	38
2003[1]	24	<3	*	3	5	224
2004[1]	24	<3	*	4	5	18
2005[1]	24	<3	*	4	6	11
2006[1]	23	<3	*	*	5	16
2007[1]	24	<3	3	4	6	11
2008[1]	21	<3	*	5	6	12
2009[1]	12	<5	*	7	8	12
Overall	**552**	**<1**	**4**	**6**	**9**	**224**

[1] The descriptive statistics for this period were estimated using a Kaplan-Meier method. * indicate that not enough non-censored data were available to make an estimate.

Nitrogen

Nitrogen is found in various forms in ecosystems including organic forms, nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+). The majority of nitrogen is in the form of a gas (N_2), which makes up approximately 80% of our air. It is converted into inorganic forms by some types of terrestrial plants (legumes) with nitrogen-fixing bacteria, lightning and microbes in the water and soil. Nitrate, the most mobile form of nitrogen, can either be assimilated by vegetation to make protein, leached into groundwater or surface water, or converted to nitrogen gas in the process of denitrification (Welsch et al. 1995). Nitrites, ammonia and ammonium are intermediate forms of nitrogen in aquatic systems and are quickly removed from the system by being converted to another form of nitrogen (NO_3^- or N_2) (Behar, 1996). Ammonium is released into the system during animal or plant decomposition or when animals excrete their wastes. Through the process of nitrification, ammonium is oxidized to nitrates by nitrifying bacteria. Nitrate concentrations in water can serve as an indicator of sewage or fertilizer in surface or ground water.

Based upon average concentrations found in water samples from 85 sites across the United States in relatively undeveloped watersheds, the median concentrations of nitrate/nitrogen and total nitrogen were 0.087 and 0.26 mg/L respectively (Clark et al., 2000). Due to land uses and atmospheric deposition, the undeveloped watershed concentrations (below 0.087 mg/L) of in-stream NO_3^- rarely occur in the Hudson Valley and the Neversink basin. Major sources of nitrate (most mobile form of nitrogen) in streams are municipal and industrial wastewater discharges and agricultural and urban runoff. Deposition from the atmosphere of the nitrogenous material in automobile exhaust and industrial emissions are also a source (Smith et al., 1991).

Nitrate in excessive amounts can accelerate eutrophication of surface waters, and can present a human health concern in drinking water. Any water that contains nitrate concentrations of 44 mg/L (equivalent to 10 mg/L nitrate-nitrogen for EPA and NYSDOH standards) or higher has the potential to cause methemoglobinemia, or "blue baby" disease in children, and the excess nitrate can indicate serious residential or agricultural contaminants (McCasland et al., 1998). Although the human health standard for nitrate consumption has little correlation with stream health, high levels of nitrate in both surface and ground water typically indicate widespread nonpoint source pollution.

The Neversink River had a median nitrate-nitrite as nitrogen concentration of 0.23 mg/l (1988-2009) with annual medians ranging from 0.11 mg/l (2000 and 2009) to 0.40 mg/l (1990).

Table 5. Annual descriptive statistics for nitrate-nitrite as N (mg/l) at Neversink River near Claryville, 1988-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1988	13	0.11	0.18	0.24	0.31	0.42
1989	27	0.22	0.29	0.34	0.42	0.73
1990	26	0.17	0.28	0.40	0.58	0.89
1991	27	0.10	0.27	0.31	0.44	0.59
1992	26	0.09	0.14	0.19	0.25	0.37
1993	26	0.08	0.15	0.21	0.26	0.66
1994	25	0.07	0.10	0.14	0.24	0.36
1995	25	0.15	0.20	0.22	0.26	0.35
1996	26	0.10	0.14	0.20	0.31	0.49
1997	26	0.07	0.21	0.23	0.30	0.52
1998	25	0.05	0.11	0.16	0.21	0.43
1999	26	0.06	0.15	0.16	0.22	0.44

2000	25	0.06	0.09	0.11	0.21	0.30
2001	25	0.07	0.18	0.24	0.29	0.85
2002	24	0.12	0.16	0.20	0.26	0.36
2003	24	0.04	0.12	0.17	0.26	0.47
2004	24	0.11	0.17	0.28	0.36	0.82
2005	23	0.14	0.21	0.23	0.32	0.40
2006	24	0.11	0.18	0.24	0.29	0.48
2007	24	0.13	0.23	0.29	0.39	0.71
2008	22	0.05	0.13	0.17	0.20	0.31
2009	12	0.03	0.09	0.11	0.17	0.32
Overall	**525**	**0.03**	**0.16**	**0.23**	**0.30**	**0.89**

Fecal Coliform

Fecal coliform bacteria are used as an indicator of possible sewage contamination because they are commonly found in human and animal feces. Although coliform bacteria are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoa that also live in the digestive tract. Therefore, the greater the numbers of fecal coliform bacteria colonies present the greater the human health risk for other pathogens. In addition to the human health risk, excess fecal coliform bacteria can cause increased oxygen demand, cloudy water, and unpleasant odors. Common sources of fecal coliform bacteria in waterways include poorly functioning sewage treatment plants, onsite septic systems, domestic and wild animal manure, and storm water runoff.

Testing for all bacteria, viruses and protozoa is very costly and time consuming. Therefore it is common practice to test for fecal coliform bacteria as an indicator of pathogens. The New York State Department of Health standard for contact recreation (swimming) is as follows: the fecal coliform bacteria density should not exceed 200 colonies per 100 ml, based on a logarithmic mean from a series of five or more samples over a thirty day period.

Although not comparable to the Department of Health standard, annual median values from the Neversink River near Claryville for the period of record ranged from 1 CFU/100mL to 9 CFU/100mL. The median value for the period form 1987-2009 was 3 CFU/100 ml.

Table 6. Annual descriptive statistics for fecal coliforms (CFU/100mL) at Neversink River near Claryville, 1987-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987[1]	26	<1	*	4	11	54
1988[1]	23	<1	1	3	6	58
1989[1]	22	<1	*	1	8	130
1990[1]	25	<1	*	1	3	13
1991[1]	25	<1	*	2	6	24
1992[1]	24	<1	*	3	12	46
1993[1]	26	<2	1	4	8	104
1994[1]	26	<1	1	4	12	194
1995[1]	25	<1	1	1	12	50
1996[1]	26	<1	1	5	9	80
1997[1]	26	<1	*	1	5	40
1998[1]	25	<1	1	6	10	188
1999[1]	26	<2	*	8	14	26
2000[1]	25	<2	*	2	8	102
2001[1]	26	<1	1	2	6	980
2002[1]	24	<1	1	6	14	50
2003[1]	24	<1	1	6	20	140
2004[1]	24	<1	1	5	10	30

2005[1]	24	<1	5	9	19	140
2006[1]	24	<1	*	3	12	67
2007[1]	24	<1	*	4	13	60
2008[1]	23	<1	1	3	14	65
2009[1]	12	<1	1	3	12	66
Overall	**555**	**<1**	*****	**3**	**10**	**980**

[1] The descriptive statistics for this period were estimated using a Kaplan-Meier method. * indicate that not enough non-censored data were available to make an estimate.

Specific Conductivity

Specific conductivity describes the ability of water to conduct an electric current, and is an index of the concentration of chemical ions in solution. An ion is an atom of an element that has gained or lost an electron which will create a negative or positive state. High conductivity is created by the presence of anions such as chloride, nitrate, sulfate, and phosphate or cations such as sodium, magnesium, calcium, iron, and aluminum. The natural conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Conductivity is often used to compare different streams because it is a cheap and easy measurement that can indicate when and where a site is being influenced by a source of contamination. Often when wastewater treatment plant effluent constitutes the majority of flow in a stream, it can be seen in water quality data due to its higher conductivity signature. Road salting practices can also impact conductivity.

Studies of inland fresh waters indicated that streams supporting good mixed fisheries had a conductivity range between 150 to 500 µmhos/cm (USEPA, 1997). The Neversink River near Claryville had a relatively low annual median conductivity, ranging from 24.2-36.0 µmhos/cm with an overall median for 1987-2009 of 28 µmhos/cm.

Table 7. Annual descriptive statistics for specific conductivity (µmho/cm) at Neversink River near Claryville, 1987-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	26	22.0	25.3	27.0	30.0	35.0
1988	26	26.0	31.0	32.5	34.0	37.0

1989	27	25.0	31.5	36.0	38.5	45.0
1990	26	20.0	28.0	32.0	36.5	88.0
1991	27	20.0	25.5	28.0	31.5	34.0
1992	26	20.0	23.0	29.5	31.0	36.0
1993	26	21.0	30.3	34.0	35.0	45.0
1994	26	24.0	27.3	29.0	31.0	34.0
1995	25	26.0	29.0	29.0	32.0	36.0
1996	26	18.0	22.3	25.0	26.8	28.0
1997	25	20.0	24.0	26.0	28.0	31.0
1998	25	16.8	23.0	26.0	28.3	33.8
1999	24	22.0	24.4	26.5	29.1	32.5
2000	25	21.1	23.1	24.2	25.4	29.2
2001	25	19.1	25.4	27.9	29.9	48.1
2002	24	22.8	26.0	27.5	30.6	32.7
2003	24	18.3	22.8	27.9	30.2	36.9
2004	24	23.0	25.0	26.7	29.6	38.4
2005	24	19.0	26.5	28.3	32.1	46.3
2006	23	18.6	24.0	25.3	28.8	31.9
2007	24	19.3	24.9	27.7	31.3	32.6
2008	22	20.7	24.1	27.1	29.4	33.0
2009	12	25.0	26.0	28.5	30.3	32.0
Overall	**562**	**16.8**	**25.0**	**28.0**	**31.1**	**88.0**

Dissolved Oxygen

Dissolved oxygen refers to oxygen gas (O_2) molecules in the water. The molecules are naturally consumed and produced in aquatic systems, and necessary for almost all aquatic organisms. If dissolved oxygen levels fall below a certain threshold, biologic integrity will be compromised. For example, on a scale of 0 to 14 mg/L, a concentration of 7 mg/L to 11 mg/L is ideal for most stream fish (Behar, 1996). Dissolved oxygen can be measured as the concentration of milligrams O2 per liter (mg/L) or as percent saturation of O_2. Percent saturation is the amount of oxygen in a liter of water relative to the total amount of oxygen the water can hold at a given temperature. In cold water systems, a percent saturation of 60% to 79% is acceptable for most stream animals (Behar, 1996).

The New York State regulations for a stream designating as supporting trout spawning states that the DO should not be less than 7.0 mg/L from other than natural conditions. Data from 1991 to 2009 indicated that the annual median DO for the Neversink River ranged from about 10.2 to 12.3 mg/L, but may dip down into the 7-8 mg/L range during hot summer months.

Table 8 Annual descriptive statistics for dissolved oxygen (mg/l) at Neversink River near Claryville, 1991-2009.

Year	N	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
1991	27	9.1	9.5	11.7	13.5	14.5
1992	26	9.0	10.0	11.8	12.8	15.0
1993	26	8.9	10.5	12.2	14.0	15.0
1994	25	9.0	10.0	11.4	13.1	14.0
1995	25	7.7	10.3	12.0	12.7	14.3
1996	26	8.8	10.2	11.4	12.2	13.8
1997	25	8.9	9.4	10.9	12.6	13.4
1998	23	7.2	9.2	10.2	12.3	13.3
1999	24	7.6	9.8	11.5	12.4	14.1
2000	25	9.2	10.1	11.1	12.5	13.4

2001	23	8.2	10.4	11.6	13.2	14.1
2002	24	8.9	10.1	11.7	13.3	14.0
2003	23	9.1	10.4	11.2	13.6	14.4
2004	24	9.2	9.8	11.5	13.3	15.9
2005	23	8.3	8.9	11.2	12.9	14.0
2006	23	8.2	10.0	11.2	12.2	13.2
2007	24	8.3	9.9	12.3	13.2	16.8
2008	20	8.9	10.0	11.5	13.1	14.3
2009	12	9.6	10.2	11.5	13.1	14.1
Overall	**448**	**7.2**	**9.9**	**11.4**	**12.9**	**16.8**

Sulfur

Sulfur in natural waters is essential in the life processes of plants and animals. Although the largest Earth fraction of sulfur occurs in reduced form in igneous and metamorphic rock, there is significant sulfur in sedimentary rock as well. When sulfide minerals undergo weathering in contact with oxygenated water, the sulfur is oxidized to yield stable sulfate ions that become mobile in solution. Another major source of sulfate in the environment is the combustion of coal, petroleum and other industrial processes such as smelting of sulfide ores. Atmospheric deposition both as dry particulates and entrained in precipitation can cause acid rain that can alter stream chemistry. Sulfate is highly mobile and often ends up in our local streams, lakes and reservoirs. Sulfate is classified under the EPA secondary maximum contaminant level (SMCL) standards. The SMCL for sulfate in drinking water is 250 milligrams per liter (mg/l).

Sulfate was not monitored by DEP until 1993. Since that time, annual median concentrations found in the Neversink River varied from 4.2 to 5.9. Sulfate values basinwide have dropped from an annual median of 5.9 mg/l in 1993 to an annual median of 4.2 mg/l in 2008 and 2009, possibly due to reduced sulfur emissions throughout the US.

Table 9. Annual descriptive statistics for sulfate (mg/l) at Neversink River near Claryville, 1993-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1993	25	5.3	5.7	5.9	6.5	6.8
1994	25	4.2	5.3	5.5	5.9	7.4
1995	25	4.9	5.4	5.6	5.9	6.5
1996	20	4.2	5.0	5.3	5.5	5.8
1997	11	4.7	5.0	5.6	5.7	5.9
1998	11	4.5	5.0	5.2	5.6	6.2
1999	12	4.4	5.1	5.3	5.8	6.6
2000	12	5.0	5.3	5.4	5.8	6.0
2001	12	4.4	5.1	5.3	5.6	5.9
2002	12	4.2	5.2	5.4	5.6	8.2
2003	11	4.1	4.8	4.9	5.2	5.9
2004	12	4.2	4.7	4.7	4.9	5.1
2005	13	4.2	4.5	4.7	4.7	5.1
2006	12	4.2	4.5	4.7	4.8	5.1
2007	12	3.9	4.2	4.4	4.7	4.8
2008	13	3.9	4.2	4.2	4.3	4.7
2009	5	3.7	4.2	4.2	4.4	4.5
Overall	**243**	**3.7**	**4.7**	**5.3**	**5.7**	**8.2**

pH

For optimal growth, most species of aquatic organisms require a pH in the range of 6.5 to 8.0, and variance outside of this range can stress or kill organisms. Due to the acidity of rainfall in the northeast, maintaining this range is of concern. According to the NYSDEC (2004a), average pH of rainfall in New York ranges from 4.0 to 4.5.

Annual (1987-2009) median pH values for the period of record for the Neversink River near Claryville ranged from 6.1 to 6.9. The annual medians were generally slightly acidic.

Table 10. Annual descriptive statistics for pH at Neversink River near Claryville, 1987-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	26	5.1	6.0	6.1	6.4	6.8
1988	26	6.0	6.5	6.6	6.7	6.9
1989	27	6.1	6.6	6.7	6.8	6.9
1990	26	5.5	6.2	6.3	6.5	6.7
1991	27	5.7	6.7	6.9	7.1	7.4
1992	26	6.1	6.6	6.9	7.1	7.4
1993	27	6.4	6.8	6.9	7.0	7.4
1994	25	6.2	6.7	6.8	6.9	7.5
1995	25	6.4	6.6	6.9	7.0	7.3
1996	26	5.5	6.2	6.3	6.4	7.0
1997	24	5.4	6.2	6.3	6.5	6.9
1998	24	5.4	6.3	6.4	6.6	7.0
1999	22	5.9	6.4	6.6	6.7	7.0
2000	25	6.1	6.4	6.6	6.7	7.0
2001	25	5.8	6.2	6.5	6.7	7.3

2002	24	6.0	6.3	6.5	6.6	6.9
2003	22	5.7	6.2	6.4	6.7	6.9
2004	24	6.3	6.5	6.6	6.8	7.3
2005	23	6.2	6.4	6.6	6.7	7.0
2006	24	5.8	6.4	6.5	6.7	7.0
2007	24	6.0	6.3	6.6	6.8	7.0
2008	22	5.9	6.3	6.5	6.7	7.1
2009	10	5.9	6.0	6.3	6.4	6.8
Overall	**554**	**5.1**	**6.3**	**6.6**	**6.8**	**7.5**

Chloride

Chlorides are salts resulting from the combination of chlorine gas with a metal. Chlorine as a gas is highly toxic, but in combination with a metal such as sodium it becomes useful to plants and animals. Small amounts of chlorides are required for normal cell function in plants and animals. Common chlorides include sodium chloride (NaCl), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). Chlorides can get into surface water from several sources including geologic formations containing chlorides, agricultural runoff, industrial wastewater, effluent from wastewater treatment plants, and the salting of roads. Excess chloride can contaminate fresh water streams and lakes, negatively affecting aquatic communities.

Concentrations of chloride of approximately 140 mg/L should be protective of freshwater organisms for short-term exposure; concentrations less than 35 mg/L are likely protective during long-term exposures (Environment Canada, 2001). Overall, approximately 5 percent of species would experience effects from chronic exposure to concentrations of chloride of 210 mg/L, while 10 percent of species would be affected at concentrations of 240 mg/L (Environment Canada, 2001). According to the United States Environmental Protection Agency, biota on average should not be affected if the four-day average concentration of chloride does not exceed 230 mg/L more than once every three years (USEPA, 2005a). Biotic impacts would be minimal if the one-hour average chloride concentration did not exceed 860 mg/L more than once every three years (USEPA, 2005a). The major sources of chloride in the Neversink watershed are most likely geology and road salting. The annual median chloride concentrations are low across the board, ranging from 1.6 mg/l to 3.3 mg/l.

Table 11. Annual descriptive statistics for chloride (mg/l) at Neversink River near Claryville, 1987-2009.

Year	N	Minimum	25th Percentile	Median	75th Percentile	Maximum
1987	26	1.0	1.5	1.8	2.3	3.5
1988	25	1.0	1.8	2.3	2.5	3.0
1989	23	1.5	2.3	2.8	3.4	4.8
1990	26	1.3	1.9	2.3	2.7	3.9
1991	27	1.4	1.9	2.2	2.8	3.3
1992[1]	26	<1	1.4	1.6	2.0	3.0
1993	26	1.5	1.9	2.4	2.7	3.6
1994[1]	26	<1	1.5	1.8	1.9	2.6
1995	25	1.5	1.9	2.1	2.4	3.0
1996[1]	26	<1	1.4	1.7	2.7	2.8
1997	26	1.2	1.5	1.9	2.2	2.6
1998[1]	25	<1	1.8	2.3	2.6	3.2
1999	26	1.2	1.8	2.1	2.4	3.2
2000[1]	15	<1	1.4	1.6	2.0	2.8
2001[1]	12	<0.6	2.0	2.3	3.6	4.4
2002[1]	11	<1	1.9	2.4	2.9	11.7
2003	11	1.4	1.6	2.9	3.5	5.1
2004	12	1.7	1.8	2.4	2.9	4.1
2005	12	1.6	2.3	2.9	3.4	5.5
2006	12	1.6	2.2	2.7	3.4	4.2
2007	12	1.4	2.5	2.9	3.3	5.3

2008	15	2.2	2.9	3.3	3.7	4.7
2009	10	1.9	2.3	2.5	3.5	4.6
Overall	**455**	**<0.6**	**2.1**	**2.7**	**3.3**	**11.7**

[1] The descriptive statistics for this period were estimated using a Kaplan-Meier method. * indicate that not enough non-censored data were available to make an estimate.

Biomonitoring

Benthic macroinvertebrates (BMI) can be simply defined as animals without backbones that are larger than 1 millimeter and live at least a portion of their life cycles in or on the bottom of a body of water. In freshwater systems these animals may live on rocks, logs, sediments, debris and aquatic plants during their various life stages. A few common examples of BMIs include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms, and the immature forms of aquatic insects such as stonefly, caddisfly and mayfly nymphs.

BMIs function at the lower levels of the aquatic food chain, with many feeding on algae, detritus, and bacteria. Some shred and eat leaves and other organic matter that enters the water, and others are predators. Because of their abundance and position in the aquatic food chain, BMIs play a critical role in the natural flow of energy and nutrients through the aquatic system (Covich et al., 1997). For example, Sweeney (1993) demonstrated in a second order stream, that leaf litter and woody debris were primarily consumed in the forested woodlot where the debris originated. Also, as benthos die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain. Insects fill the roles of predators, parasites, herbivores, saprophages, and pollinators, among others, which indicate the pervasive ecological and economic importance of this group of animals in both aquatic and terrestrial ecosystems (Rosenberg et al., 1986).

Biological assessments have been used by many states to evaluate the effectiveness of water quality programs, particularly for nonpoint source impact determinations (USEPA, 2002). For example, biological assessment models have been tested with field data and the results suggested that macroinvertebrate data collected for establishing the degree of water quality impairment can also be used to identify the impairment source with reasonable accuracy (Murray et al., 2002). In addition, it has been suggested that the percentage of chironomids in samples may be a useful index of heavy metal pollution (Winner et al., 1980). Furthermore, the Ohio EPA employs biological response signatures, based on biological, chemical, physical, bioassay, pollution source, and watershed characteristic, that consist of key response components of the biological data that consistently indicate one type of impact over another (Yoder, 1991). In New York State, the first recorded biological monitoring effort dates from 1926-1939, but the regulatory role of stream biomonitoring did not begin in New York until after the passage of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act). The primary objective of New York State's program was to evaluate the relative biological health of the state's streams and rivers through the collection and analysis of macroinvertebrate communities (Bode et al, 2002).

Biological monitoring appears to be an attractive methodology for documenting water quality for several reasons. First, the community collected at a given site reflects the water quality at that site over several weeks, months, or years. The alternative methodology of grabbing a water sample reflects the water quality at the instant the sample is collected (i.e. a snap shot image). Second, the community-based approach focuses on the biological integrity of the water body, and not a limited number of chemical parameters. Third, samples can be preserved in reference collections for future application; this provides a convenient routine of summer collection and winter analysis. Finally, biological assessments tend to be much more cost effective than chemical analysis. Table 3.1.9 lists the rationale for biomonitoring in New York State (Bode et al, 2002).

Table 3.1.9. Rationale for the analysis of macroinvertebrate communities to determine water quality of streams and rivers in New York State (Bode et. al., 2002).

1. BMIs are sensitive to environmental impacts;
2. BMIs are less mobile than fish, and thus can avoid discharges;
3. They can indicate the effects of spills, intermittent discharges, and lapses in treatment;
4. They are indicators of overall, integrated water quality, including synergistic effects and substances lower than detectable limits;
5. They are abundant in most streams, and are relatively easy and inexpensive to sample;
6. They are able to detect non-chemical impacts to the habitat, such as siltation or thermal change;
7. They are readily perceived by the public as tangible indicators of water quality;
8. They can often provide an on-site estimate of water quality;
9. They bioaccumulate many contaminants to concentrations that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain;
10. They provide a suitable endpoint to water quality objectives.

Standardized protocols for benthic macroinvertebrate monitoring were developed in the mid-1980s due to the need for cost-effective habitat and biological survey techniques (Plafkin et al., 1989). The primary driver of the development was limited economic resources available to states with miles of unassessed streams. It was also recognized that it was crucial to collect, compile, analyze, and interpret environmental data rapidly to facilitate management decisions and resulting actions for control and/or mitigation of impairment. Therefore, the conceptual principles of rapid bioassessment protocols (RBPs) were as follows: cost-effective, yet scientifically valid procedures; provisions for multiple site investigations in a field season; quick turn-around of results for management decisions, easily translated to management and the public; and environmentally benign procedures (Barbour et al. 1999). Finally, in order to save time, it was recognized that a certain degree of accuracy would need to be sacrificed, and a field-based assessment would be necessary (Hilsenhoff, 1988). Therefore, a family based assessment was developed that could be calculated in the field by professionals (Hilsenhoff, 1988). This field based assessment allows professionals to focus their time and efforts on the more in-depth analysis of areas that indicated degradation in the rapid field assessment.

In the 2004 NYS DEC issued a report entitled *30 Year Trends in Water Quality of Rivers and Streams in New York State Based on Macroinvertebrate Data 1972-2002* (Bode et al, 2004). Based on the biomonitoring data the east branch of the upper Neversink River was assesses as slightly impacted by acidity. The west branch of the upper Neversink River was assessed as non-impacted. The reach had previously been assesses as slightly impacted. The upper Neversink River at Claryville, downstream of the confluence of the east and west branches was also assessed as non-impacted.

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